Ref. No.: Ex/SC/PHY/PG/CORE/TH/107/2023

M. Sc. Physics Examination 2023

First Year, Second Semester

SOLID STATE PHYSICS

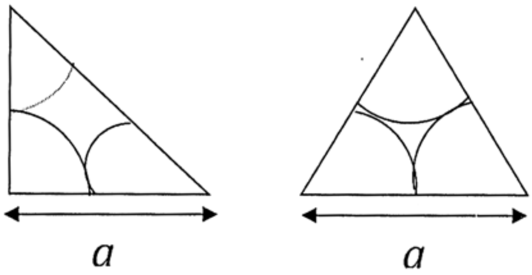
(Subject code: PG/SC/CORE/PHY/TH/107)

Time: Two hours

Full marks: 40

Answer any FIVE questions.

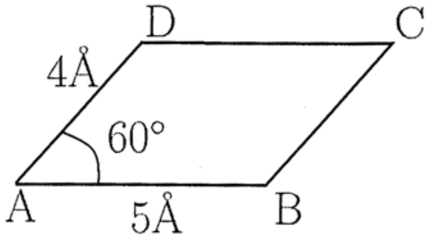
1. (a) Assuming identical atoms of radius 'r', occupying the lattice points, calculate the packing fractions of the following two 2D lattices. Which of the following lattices represent a more close packed structure?



(b) Explain with a diagram why the crystal planes in an hcp lattice can not be sufficiently described by the three Miller indices, hkl. Also discuss how the issue is resolved with the introduction of the Miller-Bravais indices, (hkil)

(c) Explain using a diagram why base centered tetragonal lattice does not exist? [3+3+2=8]

2. (a) The following diagram represents the unit cell of a two-dimensional direct lattice. Calculate the primitive translation vectors of the reciprocal lattice and draw the corresponding unit cell in the reciprocal space.



(b) What is the limitation of Bragg's law? Explain how the Bragg's law can be established using the reciprocal lattice vector. [3.5+(1+3.5)=8]

3. (a) What are the atomic scattering and geometrical structure factors? Find the structure factor for the bcc lattice.

(b) What do you mean by crystal imperfections? Calculate the number of ion pairs present in a crystal at any given temperature. [(2+2)+(1+3)=8]

[Turn over

4. (a) Find the dispersion relation for the vibration of a one-dimensional monatomic linear lattice and graphically show the Brillouin zones.

(b) Show the variations of phase velocity and group velocity with wave vector.

[(4+1)+3=8]

5. (a) State the assumptions in the formulation of Drude model.

(b) Consider the heat conduction through an insulated solid rod of uniform cross section. Now finding the net energy flux from hot to cold end obtain the expression of thermal conductivity for a three-dimensional body;

$$\kappa = \frac{1}{3} v_{\rm rms}^2 \tau \, C_{\rm V},$$

where the symbols have their usual meaning. [3+5=8]

6. (a) Derive the expression of energy dispersion relation for the three-dimensional crystal in tight-binding approximation:

$$E(\mathrm{k}) = E_A - \alpha - \gamma \sum_m e^{i\mathrm{k}\cdot(\mathrm{R}_j - \mathrm{R}_m)},$$

where R_m are the nearest neighbours of R_j. Other symbols have their usual meaning.

(b) Derive the following expressions of dispersion relations in tight-binding approximation for the BCC crystal, *i. e.*,

$$E(\mathrm{k}) = E_A - \alpha - 8\gamma \cos\frac{k_x a}{2} \cos\frac{k_y a}{2} \cos\frac{k_z a}{2}.$$

[5+3=8]

7. (a) Show that the equation of motion of the Block electron in one-dimensional periodic potential, $V(x+a) = V(x)$ is $\hbar\frac{dk}{dt} = F(t)$, where F is the external force.

(b) Show that the wave vector of a hole originated due to the missing of an electron from a otherwise filled band is given by $\mathrm{k}_h = -\mathrm{k}_e$, where k_e is the wave vector of the missing electron.

(c) Show the energy of a hole and the missing electron for a symmetric energy band is related by $E^h_{\mathrm{k}_h} = -E^e_{\mathrm{k}_e}$.

(d) Finding the expression of effective mass of electron in one-dimension, obtain the relation between the mass of hole and that of the missing electron.

[3+2+1+2=8]

8. (a) Consider a two dimensional $(L_x \times L_y)$ non-interacting electron system in the presence of a magnetic field along the z-direction $(B = B\,\hat{k})$. Write down the Hamiltonian of the moving electron.

(b) Obtain the eigenvalues and the degeneracy (D) of the eigenstates (Landau levels) by solving the Schrödinger's equation of the above system.

(c) Draw the variations of ρ_{xy} and ρ_{xx} with magnetic field B in the same diagram for the integer quantum Hall system. [2+(3+1)+2=8]